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ABSTRACT

These marine education materials are based on the approach that students learn best when given a multisensory experience. The activities are intended to develop such experiences for the visually impaired child. Activities are intended to supplement an upper-elementary science curriculum or be the basis of a unit on marine biology. The guide is organized into two sections: (1) the activity sets; and (2) background information for the sets. (RE)

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Marine Science Activities for Visually Impaired

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Introduction

The Pacific Science Center is a major resource in science education for Washington State. It has a history of developing quality science curriculum materials that offer interactive activities using physical objects.

Our philosophy is that students learn best when given a multi-sensory experience, with input through all their senses, including visual, auditory, tactile and kinesthetic. These marine education materials for upper elementary-aged students are based on this philosophy, and are designed to be especially suited to the needs of the visually impaired students. Although they emphasize input through other senses beside the visual, it is in a manner which complements the visual input. Thus, they offer a multi-sensory experience that we believe will benefit all children, making it ideal for use in classrooms where handicapped students are "mainstreamed" with other students.

This program is not meant to be a complete science curriculum. It may be used as a supplememt to a teacher's standard science program, or be the basis of a unit on marine education. It is also not necessary to do each activity in sequence. Most of the activities can be used separately, fitting into the teacher's program where appropriate. Every effort was made to use live animals, such as the clams, and real specimens (whale baleen, shells). This enhances the effectiveness of the program, but also means that many fragile items have been included, some of them difficult to replace. Care in handling the kit materials, especially the marine specimens, should be emphasized with students so that the next class will have an equally valuable experience.

This guide is organized into two sections:

1) the activity sets at the front of the book, and
2) background information for the sets at the back.

To understand the directions for each activity set, you will find it valuable to also read the related background. Our goal is to give you enough background

information so that you are comfortable teaching the activity; however, it is not necessary for your students to learn every term and marine animal discussed.

The kit of materials that accompanies this guide is available on loan from the Pacific Science Center. A small loan fee is required. Call 624-8140 and ask for the elementary teaching supervisor for more information.

The Pacific Science Center staff is always available to answer questions related to the activities, marine science, or any area of science or math where we have an expertise. We look forward to working with you to make these materials an effective part of your science program.

The funding of this program would not have occurred without the interest and assistance of Niles Wusterbarth at the Superintendent of Public Instruction, and Don Whitney and Jan Treathway, from Educational Service District #121. The greatest amount of credit goes to Holly Overman and Sally Luttrell-Montes who spent many overtime hours in converting the program from an idea into a reality. We are also indebted to the many education and marine specialists who gave us valuable input, including Vickie Brunnel, Lake Washington School District, Evelyn Simpson, Seattle School District, Elsie Marshell of the Seattle Shell Society, Judy Gidley, Shirley Pauls, Dan Tonge, and Lynn Givler. A special thanks goes to Luann Bice for her wonderful illustrations. This guide would never have been completed without the expert typing of Patty Kelley.

Finally, my thanks to Helmuth Naumer and the Pacific Science Center Board of Trustees who recognize the value of programs like this and the service they offer to the State of Washington.

DENNIS SCHATZ
Pacific Science Center

Classroom Activity Sets

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Set I: Shell Dwellers

CONCEPTS:

The student will:

1) sort and classify shells according to their texture, size and shape.
2) identify and describe five common Puget Sound marine animals.
3) recognize that these animals have external skeletons or exo-skeletons.
4) explore the simple anatomy of the clam.

PROCEDURES:

Activity 1:

Begin with discussion to gauge the students' previous experiences at the seashore. Have the students visited the beach? What have they found at the beach?

Give each student a shell. Ask them to explore their shell. Explain that the shells will be taken away, then passed back. Can they find their shells in a group of shells? Suggest that the students find at least two things on their shell which will help them identify the shell later. When each student has found his shell, discuss the clues they used for identification.

Activity 2:

Each student (or pair) receives 10 shells and is instructed to sort them into three piles any way s(he) wishes. Move around the group guessing reasons for sorting. Introduce descriptive words and phrases during this interaction which will

appropriately identify or characterize particular shells. (If students do not come up with enough descriptive words or phrases, you may wish to make a group list after the activity. Descriptions may include words like smooth, rough, ridged, curved, flat, round. Encourage comparisons such as "curved like a bowl" or "shaped like an ice cream cone".)

Activity 3:
Each student selects one shell to describe to the others. Can they find the shell from their group of shells?

Are any of the shells actually two shells hooked together? Shells which are hooked to gether are called bivalves; this word means "two doors". Clams and oysters are good examples of bivalves. Their bodies are enclosed by two shells, or valves, that usually protect the animal quite well. (See "Facts", Section I, for more information.)

If the students are curious about the spiral patterns of the moon snail, sandpaper patterns and spirals are available in the kit for further exploration. The moon snail is a good example of the spiral shape in nature. Can the students trace the spiraling pattern of the moon snail? Which direction does the snail spiral? Compare the moon snail

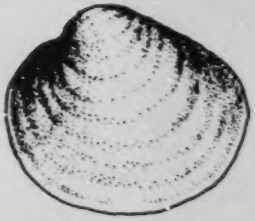
with the chambered nautilus which has many chambers coiled in a spiral. (See "Facts", Section I.)

Activity 4:

Describe on shell. Choose from the moon snail, limpet, butter clam, oyster or mussel. Suggestions for the descriptions:

moon snail - one shell; spiral-shaped; large in comparison to the other shells; feels chalky on outside but has smooth inside; light-colored.

limpet - one shell; shaped like a sun hat or an upside down cone; small; feels grainy on the outer side.



clam - actually two shells hinged together; the shells are rounded and "fat", ridges on outside; medium-sized; light-colored.

oyster - one shell (oysters are bivalves but only one of the shells is available in kit); large; smooth underneath but very rough, ridged on upper side; the ridges are large and feel boney; light-colored shell.

mussel - two shells; small and dark; shells are thin and shaped like feet; ridges on outer side are small, feel almost smooth.

Can the students find these shells as they are described? These shells are common to our Washington State beaches. Introduce their names. The students may have information to share about these sea creatures. These five shells belong to the mollusk family; some mollusks do not have shells, however. (See "Facts", Section I.)

Is the shell the animal? The students should realize that the bodies of the animals are actually enclosed within the shells and, with the exception of the moon snail, the bodies fill most of the inside of the shell.

Why do these animals have shells? Shells offer protection and support. Why don't we have shells?

Introduce the term exo-skeleton. The moon snail and other sea animals have skeletons outside of their bodies. These external skeletons are called exo-skeletons. We have skeletons within our bodies (called endoskeletons).

Shell dwellers secrete a mineral substance to form shells. (See "Facts", Section III.)

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Activity 5:
This activity requires butter clams for each student. Butter

clams are available at the Pike Place Market or at any fresh fish market. They keep in the refrigerator overnight. Before passing out the clams, use a small blade to cut the strong muscles joining the two valves. Practice opening a clam shell before the class session. It gets easier with experience!

Each student or pair of students receives a butter clam. Discuss and find the four main parts of the clam: body, neck, digger or foot, and shell. The neck and digging foot can sometimes be difficult to distinguish from the soft body of the clam. The yellowish foot feels much tougher than the rest of the clam and is usually positioned in the center of the body. The foot digs into the sand and pulls the clam along through sand like a plow. The neck is soft and quite long. Water containing food is siphoned through one of the two small openings in the dark-colored end of the neck. The food is filtered out and the water is expelled through the other siphon.

In addition to the shell, clams have added protection because of the ability to dig. If there is time, discuss the other four shells' adaptive abilities. (Limpet-suction cups; mussels-strong byssal thread. (See "Facts", Section I, for more information.)

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MATERIALS:

- sandpaper
- butter clams (for dissection)
- shells:
  - butter clams
  - oysters
  - mussels
  - moon snails
  - limpets
  - egg shells
  - bat volutes
  - razor clams
  - scallops
  - hairy tritons
- newspaper
- plastic containers
- sorting trays
- chambered nautilus

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Set II: Between the Sand and Rocks

CONCEPTS:

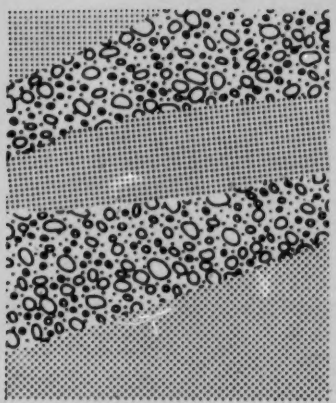
The students will:
1) investigate three different beach types.
2) explore the effect of natural forces on the beach environment.
3) determine where sea creatures can best survive based on tides and wave action.

PROCEDURES:

Activity 1:

Ask the students the following questions:
Are all beaches are the same? What are the beaches like that they have visited? Around Seattle there are three main types of beach areas (substrates).

To discover the general characteristics of these types, hand out the three different substrate samples to pairs of students. It might be helpful in understanding the term substrate by referring to a many layered cake. Each layer is of a different material. On a beach there are sloping layers consisting of one type of material or another. A substrate is the area containing a particular material. It may be a sandy substrate or a rocky substrate and so forth. (See "Facts", Section III.)



Also pass out the styrofoam trays, three per pair of students. Ask the students to pour out the contents of each substrate sample on its own

tray and examine the contents. What are the different samples like? Are they alike in any way? Screens are available if the students wish to filter the samples.

Discuss the students' findings. You can tell them that the findings represent three basic types of beach substrates around Seattle. What names would they give?

Common names are sandy beach, rocky beach, and gravel beach. Some beaches are made up of only sand, only rock, or only gravel. But many beaches have a combination of each type. In a single beach habitat or area, one could find sandy substrates, gravel substrates, or rocky substrates.

Activity 2:

Ask the students:

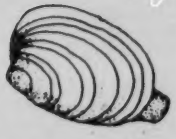
What might cause these different substrates? Some appropriate answers are that there are natural rock formations consisting of very hard rock which would not easily erode (wear down to tiny pebbles or sand). Or perhaps rivers running into the ocean carry silt and sand eroded from the land downstream to the beach.

Have the students discover how easily some rocks can erode. While experimenting, discuss ways erosion can be caused (by people, weather, and waves).

Give each student a piece of sandstone and another harder rock. Have them rub the two rocks together to get sand particles falling from the sandstone. Help the students understand that weather, water, people, and other animals cause rocks to erode. Some rocks erode faster and more easily than others. Beach habitats which are mostly sand may have cliffs of sandstone near by that are constantly eroding. On gravel beaches there may be rocks that erode into small pebbles before crumbling into sand. When you are at a rocky beach, examine the rock to determine if it is very hard or can easily crumble. It is probably very hard. There are many other reasons why a beach habitat has varying substrates. The activity is only one simplified explanation.

Activity 3:

Ask if any of the students have gone to the beach and stood in the water while the waves moved around them. What did it feel like? Could you feel the force of the waves pull at your legs? Should sea animals worry about the wave action?



Using the clam (or another seashore creature), think about what effect the waves have on where it might choose to live. Does the clam have to worry about the waves carrying it away?

Fill 2 tubs with about 2 inches of water, some sand, pebbles, and shells (use the clam, limpet, moon snail, mussel, or oyster shell). Let one person gently swish the water in the tub so a wave-like action is simulated. Let others feel what happens to the sand, pebbles, and shells. When students discover that everything moves, ask what problems this might cause the sea creatures? How might these animals protect themselves from being pulled and pushed by wave action?

Seashore creatures also have another concern. They need to maintain a certain fluid balance, protecting themselves from drying out. Ask the students to think about the tides and what areas of a beach are almost always wet, sometimes wet, or wet only occasionally.

If your students want to see the animals that must be underwater most of the time, they should go to the beach at low tide or visit a touch tank at an aquarium. To see the animals that do protect themselves from drying out from the sun and air, the students should walk where the water comes, except at a very high tide. (See "Facts", Section II). These intertidal animals have special ways of protecting their soft bodies from the drying air.

Ask the students to recall the moon snail, limpet, oyster, mussel, and clam from the previous set of activities, or find out with which seashore creatures they are familiar. Will they dry out if they live in the high tide zone where the water only reaches it occasionally?

Let's see how animals can protect themselves from the force of the waves and keep themselves from drying out. Listed below are local sealife. Allow the children to explore the shells in Set I again. Ask them to think about the effects of wave action and tides on these animals. The related facts for each animal will assist the students in making reasonable conclusions.

Use the clam first if the students have completed the exploration in Set I. Refer again to two basic needs for the animal to survive with the wave action and tides.

(a) The animal must have a way to avoid being tossed around by the waves.
(b) The animal must be able to keep his body from drying out. (See "Facts", Section I, for more detailed information.)

Determine the number of animals for exploration by the attention span of the class.

Clams: Closing the shell protects the soft-bodied animal

from drying out and it has a digging foot which allows it to burrow in the sand.

Limpets: The soft body part fits into the cone-shaped shell completely when the limpet is on a rock. This protects it from drying out. The limpet hangs on to the rock with its strong muscular foot.

Moon Snails: (Use snail if available.) The moon snail not only has its shell to protect its body from drying out; it also has a door-like feature called an operculum which feels like a strong fingernail. This operculum closes the opening at the base of the snail shell reducing the water loss. The snail can burrow into the sand with its muscular foot.

Mussels: Mussles are attached to rocks by byssel threads. Mussels also live together in groups to protect themselves from the wave action. Their shells can keep in moisture and drying air out.

Oysters: Oysters often attach themselves to hard surfaces such as rocks with a type of cement and can close their two shells against the drying air.

Activity 4: (Optional)
To understand how the amount of water which covers an animal can protect it from drying out, try this simple 24-hour experiment. Use a peeled

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banana to represent a soft-bodied marine animal. Cut the banana into three parts. Immerse one part in water; dampen the second part several times during the day; spray the third piece only once with a plant sprayer. Place each piece of banana under a strong light. Keep the light on at least during school hours. Examine the pieces the following day. What has happened to each piece?

MATERIALS:

Activity 1:
plastic containers with substrate samples
sorting trays
screens

Activity 2:
dishpan
container filled with half sand and half pebbles
water
sandstone
smooth, hard rock

Activity 3:
A class set of the following shells:
- clams
- mussels
- moon snails
- limpets
- oysters

Activity 4:
banana
lamp
plant sprayer
water container

Set III: Bone or Shell?

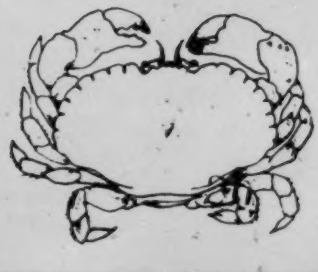
CONCEPTS:

The students will:
1) distinguish between endo- and exo-skeletons.
2) recognize that bones and shells are made of the same mineral and share similar functions.

PROCEDURES:

Activity 1:
Review the function of an exo-skeleton. Ask the students to recall that shells are outside the soft body of the animal and can be called exo-skeletons. Remind the group that the exo-skeleton protects the animal. Let's call the exo-skeleton the "hard part" of the animal and the other parts the "soft parts". Ask what other animals have hard parts and soft parts. If the students need help, guide them into thinking of a turtle, bird, or man. Encourage the group to think about hard parts which are inside an animal, such as bones in humans.

What gives our body shape and support? (Bones.) Introduce the term endo-skeleton to cover the boney skeleton found inside man and other animals. (For more information, see "Facts", Section III.)



Pose the following questions to the students:
How are bones like shells? What do bones do for us that the shell does for the moon snail? (Both endo-skeletons and exo-skeletons protect, support, and some also aid movement.)

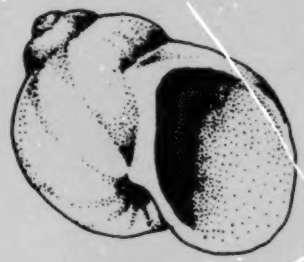
Pass examples of bones and shells to students. Have the students make comparisons as to surface texture, size, shape, possible function, and thickness of the bones and shells. Which object seems thickest? Do all the bones and shells feel the same? Do they have similar shapes?

Both bones and shells are made from calcium carbonate but are produced in a different way. (See "Facts", Section III.)

Activity 2:
Begin this activity with a discussion. Are all "hard parts" of the students' bodies bones? Ask the students to examine their fingernails, toenails, ears, nose, and teeth. Can they feel how flexible the end of their nose is? Each ear?

Pass out the human bones, animal bones, cow horn, cartilage, and teeth. Do not tell the students what they are. Have them determine which pieces are bone and which are not. Discuss the differences found. Cow horn, like fingernails, is protein. Cartilage is flexible and exists in our noses and ears. Teeth feel like bones but are made with material other than calcium carbonate. Teeth are the strongest hard part in our bodies. The chemical and physical characteristics of bone, teeth, cartilage, and

fingernails are different from one another yet they serve similar functions. If the students have trouble with "chemicals", use the phase "building blocks". (See "Facts", Section III.)



How do hard parts in various animals compare when you examine them? Why are some animals' bones so much larger than others? Students may explore a complete animal endo-skeleton or exo-skeleton. Options: Explore bivalves, snails, Oregon tritons, shark jaws, turtle, fish, rat included in the kit.

MATERIALS:

skeletons
cow horn
bones
a class set of shells
  bivalves
  snails
  Oregon tritons
teeth
cartilage

Set IV: Joints and Movements

CONCEPTS:

The student will:
1) recognize the importance of joints to our movement as well as the movement of other animals.
2) explore the movement of the shore crab.

PROCEDURES:

Activity 1:
Review the importance of the functions of bones. Ask them to guess how many bones our bodies have? (There are over 200 bones in the human body.) Why do we have so many?

Look at the human hand or foot. Bones are connected with cartilage; since cartilage will not be on the skeleton, use a sample of cartilage for the students to feel. Cartilage is available in the kit. Have the students discovered cartilage while eating a piece of chicken? (The skeletons of sharks are cartilage, not bone!)

Explain bones as rigid supports, cartilage as the elastic or pliable connections, and muscles as the movers. Joints are the connection between two bones. Whenever separate bones meet one another, a joint is formed. Not all joints are movable but, for our purposes, we will only look at the movable ones.

Where do we have movable joints? Can the students move all of their joints at once?! What if we did not have joints?

Give each student two cardboard tubes. Have the students slip their arms in the tubes until their elbows are covered. The students may need assistance with the tubes. Can they write their names? Tie their shoes? Put on a jacket? Make up other experiments to test the need for joints.

Activity 2:

Do other animals have joints? Ask the students to look at a crab claw. Where are its joints? Explain that, unlike our joints, the joints are actually thinner and more flexible extensions of the harder exo-skeleton.

crab claw

With a live shore crab, allow the students to feel its movements in their hands. How does he move? Does the shore crab have joints in each claw?

Place the shore crab in a shallow pan of water. When everyone has gently handled the crab in the water, discuss the crab's movement. Do the front claws aid his movement?

Discuss the front claws' functions. In most crab species, the front claws or pinchers serve to protect the crab and assist in finding and eating food. The other claws help the crab move. Pass out two oven mitts to each child to simulate the grasp of the crabs' front claws. Can the

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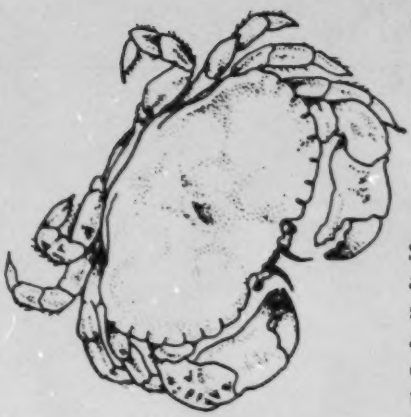


students pick up a pencil? Have them try picking up other objects or feeding themselves.

If there is room, ask the students to imitate the shore crab's movement. What direction does the crab move? Are the movements slow or fast?

Shore crabs can be found on almost any beach. Many pet stores also sell them. They are easy to care for in the classroom for a short period of time. Keep the shore crab in cool water until it can be returned to the beach. Although they make the pinching movement, the shore crab's pinchers will not hurt the students.

Activity 3 (Optional):
This activity will allow students to apply their understanding of joints to create imaginary sea animals. Pass out a variety of building materials (clay, pipe cleaners, etc.) to each student. Ask the students to create an animal that...catches fish with its back legs or...digs with every foot. The students may have more imaginative possibilities!

Share the creations.

MATERIALS:

cartilage
shore crab (live)
crab claws
human hand skeleton (or foot)
shallow plastic tub
cardboard tubes
clay
pipe cleaners
oven mitts

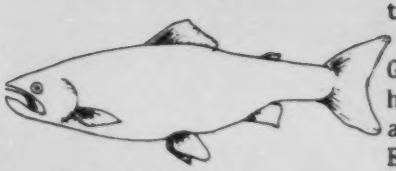
Set V: Fish or Marine Mammal?

CONCEPTS:

The students will:
1) explore and define the properties of a fish.
2) distinguish between a marine mammal and a fish.
3) identify different characteristics of whales for classification.
4) develop a better understanding of the size of a whale.

PROCEDURES:

Activity 1:
Determine what the students know about fish. What are some general characteristics? How do they breathe? Do they have teeth? What do they use to move through the water?



Give each student an anchovy or herring. These are available at fish markets or bait shops. Explore the streamlined shape. Locate the gills, mouth, teeth, scales, and fins. A diagram of the anchovy and its parts is included in "Facts", Section IV. Can they find any ears? (Fish do not have ears like ours. They have a special lateral line to assist them with hearing. See "Facts", Section VI.) Encourage the students to describe the fish. What does the "skin" feel like? The smell of anchovies and herring is quite distinctive. To avoid a lingering smell in the classroom, make sure the fish scales do not remain on desks or rugs.

Can the students feel bones in the fish fin? Have the group

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examine the skeleton of a perch to compare the endo-skeleton with the outer anatomy. Are the fin bones jointed like our hand bones? Why not? (Animals do not need to move on land or pick up small items.)

Feel the backbone and talk about it being jointed like our own backbone. Why are the joints important here? (The fish needs flexibility to wiggle its body while moving through the water.)

Activity 2:

Divide the students evenly between the models of the baleen whale, toothed whale, and porpoise. Explore the features of each animal. Let students look over each model. Tell the students to use the accompanying human figures which have been scaled down to develop an idea as to how large each animal is in relation to man.

After each animal has been explored, discuss the characteristics the students found. How are these models like the fish? (Students might need to use the salmon model here.) Possible answers might include the similarity of stream-lined shapes or the existence of fins. All of the animals are found in the sea, but they are very different from fish. These animals are all mammals. Try to let the students define the necessary

features of a mammal. (A mammal nurses its young, can breathe only out of the water, does not lay eggs, and is warm blooded.) Ask the students to name familiar mammals and non-mammals such as birds, reptiles, fish. Clarify why a fish is not a mammal. (It lays eggs, does not nurse its young, is cold blooded, and breathes underwater with gills.)

Have students guess how whales and porpoises breathe. How do we breathe? Can you locate anything which might serve as a nostril(s) for the marine mammals? Remember all these animals must breathe air above the surface of the water. Locate the one or two nostrils on top of the head. Why might this be a better location than on the front of the head? The nostril(s) is called a blowhole. When the animal dives underwater a valve covers the blowhole to keep water out of the opening.

Inside the mouth are variations, too. Make sure students can distinguish between the different mouth structures. In two models, there are teeth-like shapes in the mouth; in another there are flat plates which feel brush- or hair-like at the end. These plates are called baleen.

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When students are ready, read the questions from the simple classification key to determine

the common and Latin names for each mammal.

Keys are used by scientists for observing and classifying trees, insects, rocks, etc. Although there are only three models of marine mammals, this activity will help the students to make careful observations and logical decisions and to distinguish between characteristic properties. Keys are fun, too.

CLASSIFICATION KEY FOR CETACEANS (Read Aloud)

1a. Is there an absence of legs at the back of the animal?

Yes Move to 1b

No Clarify what legs are. There should be no back appendages for moving on land.

1b. Can you find front appendages (like flippers) or arms) on each side?

Yes Move to 2a.

No Look again.

2a. Does the animal have a fin on its back? It is called a dorsal fin.

Yes Move to 3a.

No Move to 4b.

2b. Is the dorsal fin high and triangular shaped?

Yes Move to 3a.

No Move to 3b.

3a. Are the side fins shaped like a ping-pong paddle (very rounded) at the end?

Yes You have found the killer whale Orca.

No Move to 3b.

3b. Are the side fins a triangular shape with a dull point at the end?

Yes Move to 4a.

No Recheck for high dorsal fin (2b).

4a. Is the mouth beak-like with 18-26 teeth in each jaw?

Yes You have found the bottle-nosed dolphin.
No Recheck for killer whale characteristics (2a).

4b. Does the animal have long flat plates hanging down from its upper jaw which feel brushy or hair-like at the ends? These plates are called baleen.

Yes You have found the right whale.
No Try to key out killer whale or bottle-nose dolphin again.

Activity 3:

The models do not give accurate size dimensions. To get a better idea of the size of the mouth of the whale, instruct the students to feel the baleen. Do they have any idea what it might be? What does it feel like? Explain that some whales do not have teeth. They do not eat large animals but collect animals which are so small that we need to see some of them under a microscope. These whales are called baleen whales. These large animals move through the water with their mouths open but they do not take in everything in the water. The baleen hangs straight down from their upper jaws; the hairy or brush-like parts on the baleen capture the small animals while the larger animals cannot enter because the whale has up to 350 pieces of baleen in a row. The kit contains baleen from two different whales; the bowhead and the gray whale. What can the students tell about each whale from its baleen? The short, white, bristly baleen is

from the gray whale. The long, darker, hair-like baleen is from the bowhead whale. How does the food get to the whale's stomach? Ask the students to answer this using their own mouth. How do we get food off our teeth and down to our stomach? (Tongue.) Baleen whales use their enormous tongue to lick off the small animals and then swallow. All the water which entered their mouth gets pushed back out. Some baleen whales have pieces of baleen 4 meters (12 feet) long. (See "Facts", Section VI.)

To help the students further grasp the actual size of the whale, porpoise, and salmon, use the "length strips". Let children hold the ends of the cord strips while the other children walk along the length of each to compare sizes. The longest strip represents the baleen whales, the next longest will be the toothed whales, then the porpoises and dolphins, and finally the salmon. This activity might best be conducted outdoors for the average bowhead whale is 16-17 meters (around 55 feet

MATERIALS:

anchovies or herring
bowhead and gray whale baleen
whale, porpoise, salmon models
fish fin
length cord strips
perch skeleton
human hand skeleton

Set VI: Stalking the Seaweed

CONCEPTS:

The student will:

1) become familiar with three different forms of seaweed.
2) recognize the major parts of a seaweed and their functions.
3) understand why algae is different from most green land plants.
4) understand the importance of these plants as a food source to sea animals and humans.

PROCEDURES:

Activity 1:

Begin this activity by asking the students to name a familiar plant. Could this plant grow underwater? Explain to the students that our seas and lakes have plant growth too. Do the students think sea plants and land plants would be alike? Why or why not?

Pass around the algae samples included in the kit. (While the dried specimens provide some information about the shape and form of seaweeds, live specimens are preferable if available. If you collect seaweeds at the beach, check the local regulations for removing marine plants and animals first.) The seaweed samples include rockweed (Fucus), turkish towel (Gigartina exasperata), and sugar wrack (Laminaria saccharina). Ask the students to describe what they feel. Which sample resembles the feeling of the rough towel they use to dry their face? Which

Rockweed

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one seems to be "swollen" at the branch tips?

Introduce the seaweeds' common names. The names are written on the back of each specimen mount. Can the students make up other names for the seaweed?

Activity 2:
Pass around the sugar wrack, a characteristic seaweed. Do seaweeds have different parts? Explain that most seaweeds live attached to a hard surface; which part of this seaweed is used to hold onto a rock? One end of the seaweed works like a primitive root system; it is called the holdfast and this secures the seaweed to rocks. The seaweed stalk is called the stipe; the broad leaf-like section the blade. Can the students identify each part?

Which part feels as if it could soak up the most sun? Do the students think seaweed could live deep in the ocean? Some seaweed species float on water but most seaweed live along the fringe of the ocean where they can hang onto rocks and thus remain in shallow, well-lighted water.

Ask the students to imagine they are a seaweed. How would they reach to the surface of the ocean to catch the sun's light? Popping wrack, common to Washington's coast, has gas-filled bladders attached to their stalks. These hold the

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seaweeds upright in the water. Many microscopic plants extend their bodies to keep afloat. Have the students ever tried floating in water with their arms out? With their arms close to their side? Which was was easiest?

Explain to the students that we see only a small sample of the abundant supply of water plants. Although we find seaweed washed ashore by waves, most seaweeds lie hidden offshore. Only a portion of seaweed are visible in water. We do not see all of land plants, either. We see the branches, leaves and flowers of land plants but below the ground lie the roots firmly embedded in soil.

Pass around the land plant specimen. Compare its characteristics to the seaweed. What is different? What is alike? How do land plants get the water they need? The nutrients? Land plants have root systems which supply them with necessary water and minerals for life and growth. Seaweeds do not have roots, stems, or leaves. They absorb nutrients from the water.

Activity 3:

Algae are sample plants usually growing in water or damp places. Phytoplankton (microscopic plants) and seaweeds are kinds of algae. Algae are important to the animals in the sea and to us.

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Ask the students to examine the pressed algae again. Explore ways in which the algae might serve useful purposes. Why might animals like to live around the seaweed? Algae can be a home, a hiding place and a food source for these animals. If the students were to examine a clump of seaweed found on the beach, they might discover such creatures as sea urchins, starfish, scallops, and hundreds of sand fleas among the blades.

If animals can eat seaweed, why can't we? We can! Some seaweeds are eaten in their natural state; most are dried and used in soups and stew dishes. The Japanese, in particular, use seaweed and other seafoods. (See "Facts", Section IV, for seaweed recipes.)

Discuss textures of the foods they like. Do the students like crunchy foods? Slimey foods? Are there many things we have been "taught" not to like that are really quite good?

MATERIALS:

dried specimens of rockweed, turkish towel and sugar wrack
dried specimen of a land plant

Set VII: Vibrations Around Us

CONCEPTS:

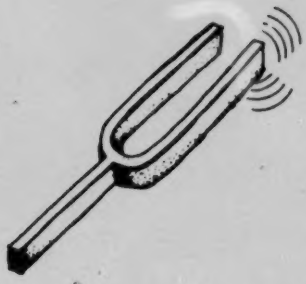
The students will:
1) recognize that sound is caused by vibrations.
2) understand that sound waves travel through air and liquids.

PROCEDURES:

Activity 1:
Make a loud noise (i.e., a clap). What is it? How do we know? Lead into a discussion on how we hear. What causes sound?

Scientists tell us that sounds are caused by an object vibrating rapidly. When something moves back and forth, we say it vibrates.

For a better understanding of vibrations, experiment with rubber bands which vibrate easily. Instruct the students to place the rubber bands between their teeth. What happens when they stretch the rubber band out and pluck it? Can the students feel the vibrations? What must the students do to the rubber band to make a vibration? Explain that vibrations are the movement of an object and the air around it after the object has been struck against something else.



Activity 2:
Introduce the students to tuning fork. Tuning forks offer an excellent way for the students to experience sound as vibrations.

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Give each pair of students a tuning fork and instruct them to strike it. The students should hold the stem of the tuning fork, hit the pronged end against a block of wood, then hold the fork close to their ear. What happens?

What do the students hear? Does the sound change if the students hold the tuning fork farther away from them? Instruct a students to put a finger gently in his ear. Strike the tuning fork and place the stem to the tip of his bent elbow. The vibrations should travel through the bones to the ear. Take turns experimenting with this activity.

Ask the students to place their tuning forks in water. What happens when the fork touches the surface of the water? Can the students feel a ripple?

Activity 3:

Ask the students to listen as a bell is rung under the surface of the water in the dishpan. Do they hear the bell? Now instruct them to place rubber tubes in water while the bell is rung again; are there any changes in what they hear? Does sound travel beyond water? Compare these sound experiences with the ringing of the bell outside of the water.

The students will probably have reached the conclusion that

sound does travel through water, but we do not hear as well there! Obviously, the structure of our ears is best adapted for hearing on land but we can hear sounds in water, too. (See "Facts", Section VI.)

Suggest that the students try talking while immersed in their bathtub at home. The best experience in exploring how sound travels in water will probably be the students own underwater experiences!

Activity 4:
Sound travels through air but we cannot see it. If we could see sound, it would be described as a type of wave motion.

Discuss the movement of waves. What is the shape of waves? Give the students cards with sandpaper outlines. They may wish to practice making in the wave motion in the air; the teacher can make the motion with the first student who passes it on to the other students, just as a sound wave is passed on from molecule to molecule in air or water.

Although the movement of sound waves is described as like the motion of waves, sound waves can be shaped differently. Sound waves can spread throughout an entire room; they must travel in all directions. (See "Facts", Section VI.) Sounds can be channeled, too.

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Group the students in pairs. Instruct them to take turns listening to each other whisper through a long rubber tube. Can they hear each other if the tubing is held away from their ears? How far away can they hold it and still hear the whisper? Could the same whisper be heard without the tubing? How is the sound being channeled? Can the students feel vibrations if they place their hands on the tubing?

Our ear canals operate in a similar way to channel sound vibrations to our middle ear. (For more information, see "Facts", Section VI.)

MATERIALS

tuning forks
pan of water
vinyl tubing
wrist bells
clickers
rubber bands

Set VIII: Sounds from the Sea

CONCEPTS:

The student will:
1) become familiar with certain sea sounds.
2) distinguish between various ship warning signals.
3) understand that some marine mammals have special communication.

PROCEDURES:

Activity 1:
We have spent time exploring some of the sealife at the beach. The seashore has many sounds, too.

Listen to a recording of seashore sounds. What do you hear? (Waves, water birds.)

What can we learn from these sounds? Emphasize that sounds communicate many things to us. What sounds are happy sounds? Do the students have favorite sounds?

Activity 2:
Ships send signals which give us important information. How do ships send signals? Standard means include radio, telegraph, guns or explosives, flares, beacons, flags, foghorns, whistle blasts, etc.

Why would sea captains need to know these signals? When should the signals be used? Explain that in times of distress sea captains would need to use signals for assistance. Navigation rules demand that ships give signals to indicate the directions they are traveling when approaching

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other vessels. Signals should also be given when visibility is poor to indicate their presence and when vessels overtake one another.

Perhaps the students have heard ships signal bridge operators when they wish to have the bridge raised so they may pass under it. Listen to the cassette recording of some basic ship signals.

These signals are but a few of the many used by ships everywhere.

• short blast 2 seconds
— prolonged blast 4-6 seconds
—— long blast 8-10 seconds

The following recorded signals are used when visibility is good:

• Two vessels are directly approaching each other; signal indicates each should turn to the starboard (right) side for passing.

•• Two vessels approach each other; each should turn to port (left) side.

••• Indicates the engines are going astern (backward). This signal is used when the two approaching ships have not come to an agreement for passing.

•••• Man Overboard!

••••• Five or more short blasts in rapid succession indicates danger.

—— As a ship approaches a river bend or an area that

cannot be seen, this signified its approach at a half mile away.

— •• Tugboat with a tow.

These signals are used when visibility is poor, as in a heavy fog:

•/• one short every minute; ship is underway.

••/•• two shorts in rapid succession; ship is free

What signals do the students think are especially important? Why?

Sailboats often use these signals, too; most signals are made with sharp sounding whistles.

A foghorn is included in the kit. Weather permitting, the students may wish to practice duplicating the signals or make up their own warning signals. A note of warning: the foghorn is quite loud and should only be used outside. It may be a good idea to warn other teachers so they will not be alarmed!

Activity 3:

Man is not the only living creature that uses sound for communication. Many whales and porpoises communicate information also. Scientists believe they may have a sophisticated form of communication, perhaps even a language. They communicate to

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each other; they may even be trying to communicate with us. Scientists are only beginning to understand their ways of communication.

Listen to the recording of the sounds of the humpback whale. (See "Facts", Section V.) What do the sounds remind you of? Can the students imitate the sounds?

When we speak vibrations caused by our vocal cords create sound. Ask the students to press against their vocal cords as they speak to feel the vibrations.

Whales and porpoises do not have vocal cords. How do these whales and porpoises make sounds then? If available, use the marine mammal models to assist the students with their theories.

There are several theories on how sound is made by toothed whales and porpoises. Most scientists feel that the sounds, both on the surface of the water and underneath, come from the blowhole. (See "Facts", Section V.)

Discuss why whales and porpoises go to the surface of the water. They must take in air through the blowhole very rapidly; consequently the sound is very loud. This "whooosh" sound can be heard miles away. Imitate the sounds made when

the whales blow out and take in air. The students may be interested to know that while we can hold our breath only for short periods of time, one whale species can stay underwater for as long as two hours. On the average, however, whales can hold their breath for approximately 20 minutes.

Activity 4:

Porpoises and some whales also have a special ability for locating food. Because whales and porpoises do not see well in dark, murky water, the use of sound is of primary importance. These marine mammals make clicking sounds, probably through their blowholes, which create echoes. The echoes assist them in locating food. Sounds are also used by these mammals to furnish information about the underwater terrain and to keep in contact with each other. This ability to create and receive information from sounds and their echoes is called echolocation. (See "Facts", Section VI.) The students can duplicate the clicking noises by running their thumbnails across a comb.

Demonstrate echolocation by asking the students to form a large circle around a student who will be the "porpoise"; the other students are the "fish" in the sea. The porpoise and the fish should all have

clickers. The "porpoise" cannot aim his click at a particular target; he makes the sound and an echo of that sound returns if an object, such as a fish, is nearby. Select a fish to be the target; h/she will pretend to be near the porpoise in order to echo back the clicking sound. The porpoise makes a sound with the clicker. Without looking, can the porpoise tell which fish has returned the echo? The porpoise should point in the direction of the "fish".

Explain to the students that "real" fish do not conciously return the clicking sound. The porpoise hears the echoes as they bounce back off the bodies of the fish as our voices might echo off the walls of a gym.

Echolocation among whales and dolphins is still not fully understood; it continues to be an area of much study.

MATERIALS:

foghorn
fiberglass models
combs
cassette recording(s)
clickers

About a Field Trip to the Beach . . .

A visit to the beach would greatly enhance any or all of the activities presented in this guide. We are lucky to live in a coastal environment which offers many opportunities to explore beaches and intertidal life. An excursion to the beach is most successful, however, when careful thought and planning are a part of it. The following general considerations should be kept in mind:

1) Explore the beach or tidepool site before the field trip. Finalize plans only after knowing the kind of beach to expect, the access route to the beach, where restrooms are, and so forth. If there are handicapped students, accessibility is especially important.

2) Remind the students to wear proper clothing for the beach. They should be prepared for cool, rainy weather and be outfitted in boots or shoes that can get muddy.

3) Explain to the class the necessity of protecting the beach; it is the home of many plants and animals. Pick up anything that was brought into the area. Put all animals and shells back where they were found. Students will comply to these rules if they understand why they were made.

4) Study the tide tables when choosing a convenient time and

place for the field trip. Plan enough time to arrive before low tide. Seaweeds and marine animals are most visible at low tide.

5) Allow for enough chaperones to keep the group manageable.

At the beach or tidepool area, be enthusiastic about what is found and what ideas are shared. It should be a fun excursion for everyone! The Seattle area has many interesting beaches for field trips. Discovery Park in Magnolia, Golden Gardens in Ballard and Alki Point in West Seattle offer a variety of intertidal marine life.

IF YOU HAVE SPECIAL STUDENTS... As with all students, it is easy for teachers to underestimate special students' capacities for understanding information presented. It is important to allow them to participate and learn at the limit of their ability. Special considerations should be given to the needs of these students but you should not to exaggerate the considerations. Perhaps the students can be given special tasks which will contribute meaningful information to the entire group. A blind student, for example, can be given the special task of recording the sounds of the beach, such as the variety of water bird sounds.

All students learn best by doing so encourage the students to handle as many seashore objects as possible. Allow enough time for this exploration; there are undoubtedly a variety of learning paces within the class.

Your students may need guidance in maneuvering on the widely varied terrain of the seashore. Since teachers need to be free for supervising the entire class, a classmate or friend can help. The classmate should be able to relate observations in an interesting way.

If your class will be working with a naturalist or a park staff member, alert them to your students' special needs. They can assist you in seeing that the benefits of a field excursion for your special students are the same as they are for anyone.

Not-So-Dry Facts
About Wet Issues

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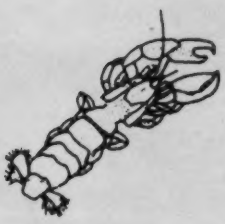
Section I: Seashore Invertebrates



Many marine organisms are mentioned throughout the activity sets. Most are common to Puget Sound. For a better understanding of these organisms, the following section provides general information on the major marine invertebrate phyla, or groups, and their important representatives. Each phyla name is capitalized; the specific animals are underlined. The information provided may be useful for follow-up activities and on field trips.

The diagram on the following pages illustrates the phyla. In the text descriptions, a key is used to indicate where the marine organisms are most likely to be found. The key is as follows:

rocky pebbly beach

sandy or muddy beach

open water

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PORIFERA

Sponges

CNIDARIA

Hydrozoa
Hydroids

Soyphozoa
Jellyfish

Arthozoa
Sea anemones

ANNELIDA

Polychaeta
Segmented worms

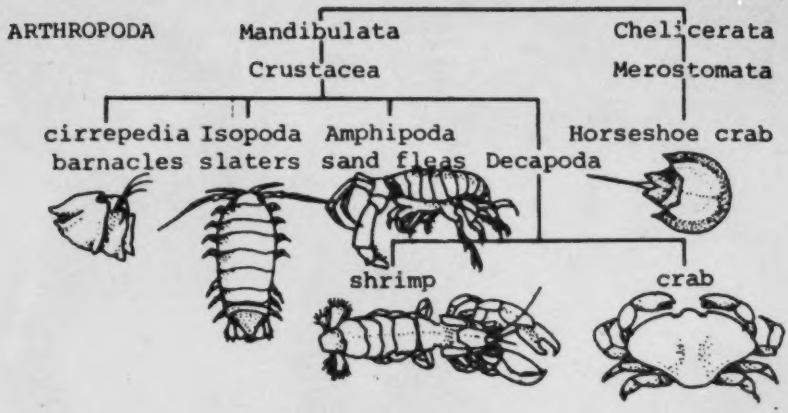
MOLLUSCA

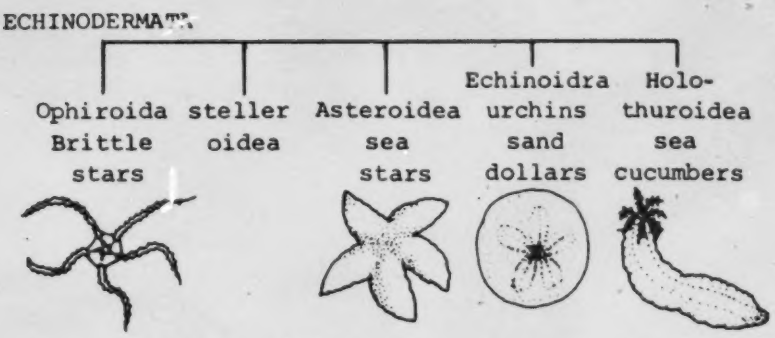
Polypla-
cepkela
Chitons

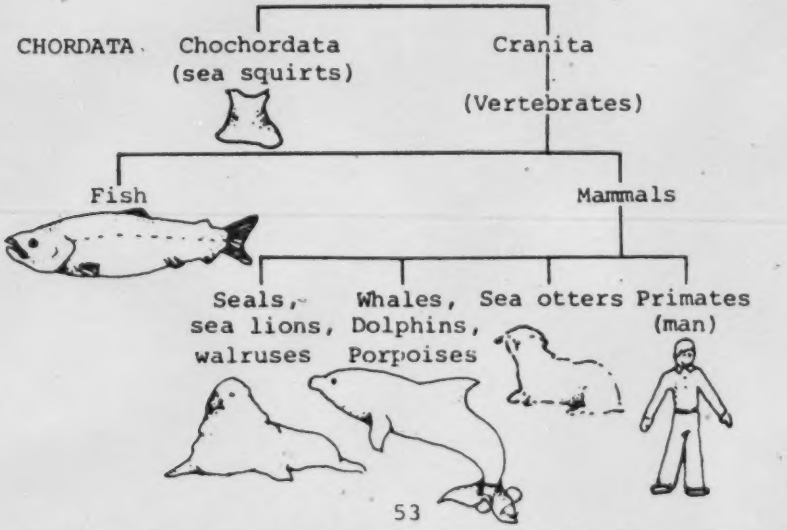
Gastropoda
Snails,
seaslugs

Vivalvia
Clams,
mussels

cephalopods
Octopuses,
squids


ARTHROPODA
Mandibulata
Crustacea
Chelicerata
Merostomata
cirrepedia
barnacles
Isopoda
slaters
Amphipoda
sand fleas
Decapoda
Horseshoe crab
shrimp
crab


ECHINODERMATA
Ophiroida
Brittle
stars
steller
oidea
Asteroidea
sea
stars
Echinoidra
urchins
sand
dollars
Holo-
thuroidea
sea
cucumbers


CHORDATA
Chochordata
(sea squirts)
Cranita
(Vertebrates)
Fish
Mammals
Seals,
sea lions,
walruses
Whales,
Dolphins,
Porpoises
Sea otters
Primates
(man)

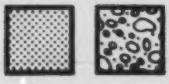
PORIFERA

The Sponges

It may seem difficult to believe that sponges are actually animals not plants. They are primitive, often formless, animals composed of specialized cells which function together without forming true tissues. Sponges have no head, eyes, fat, arms, or mouth. They have an inside layer and an outside layer. As water moves through the sponge, pieces of food are swallowed by the cells of the inside layer. Some sponges feel spongey, but those which contain more silica and calcium carbonate are much stiffer and rougher. These hard parts are considered to be parts of the skeleton of the sponge.

CNIDARIA

Hydroids, jellyfish, and sea anemones are all cnidarians, which means they are all composed of definite tissues, have radial symmetry (see glossary), and probably have tentacles. They may be free-swimming or attached during part or all of their life cycles.



The sea anemone (class Anthozoa) looks like a brightly colored plant. It attaches to a surface where it can avoid drying out its soft gelatinous body. The oral end (where the mouth is located) of its column-shaped body is fringed by tentacles which catch food and carry it to the animal's mouth. From its tentacles the

sea anemone can shoot out poison darts attached to slender threads. When a target is hit, the tentacles wrap around the animal and bring it to the sea anemone's mouth. The tentacles can be very thick, if the sea anemones eat large organisms, such as fish.

The jellyfish (class Scyphozoa) can be grossly viewed as a sea anemone floating upside down. It looks more like a beautiful umbrella, opening and closing as it swims. Powerful muscles make it capable of vertical movement, but horizontal movement is usually controlled by currents or waves. The jellyfish uses its tentacles, equipped with stinging capsules and its arms, which surround the mouth, to catch its prey. The "mouth arms" hang from the underneath side of the umbrella-shaped body.

ANNELIDA

(Marine Worms)

The great majority of segmented worms found in the marine environment belong to the class Polychaeta. The generalized polychaete has a well developed head, paired fleshy appendages attached to each segment, and bristle-like structures which arise from the appendages. These structures aid in movement. Polychaetes may be free-crawling, burrowing, or tube-dwelling. Many different modes of feeding are used. Variations on the worms' basic body plan reveal specialized

adaptations.

Certain worms secrete a calcareous tube around themselves. This tube dwelling worm attaches to a hard surface. When covered with water a feather-like structure at the head end of the worm is extended to capture bits of food. The worm can completely withdraw into its tube to avoid predation and dessication (drying out).

MOLLUSCA

The phylum Mollusca has many representatives with external shells, remants of shells, or no shells at all. Most mollusks are characterized by a soft body with part of the body wall growing around it in a kind of flap, called the mantle (See "Facts", Section III). Another characteristic is the muscular foot whose function and development varies according to the need of the animal.

The chiton (Class Polyplacophora) has eight overlapping shells or plates. Its large muscular foot makes it capable of slow movement or tight adherence to the rocky surface on which it lives. Chitons have home spots to which they return. Their shells wear away deep marks on the rock face. After generations of use the marks become very deep. Some homes are estimated to be hundreds of years old!

Limpets, oyster drills, and moon snails are all gastropods, mollusks that possess a more obvious head than the chitons. Like the chiton, they have a large crawling foot. Some gastropods have one shell and others, such as the common slug, have no shell.

The limpet has a cone-shaped shell. It uses its large foot to crawl and to suction itself onto hard surfaces, thus guarding against easy removal by a predator or by the surf. The foot also helps prevent loss of moisture due to heat or wind when the animal is out of the water. Limpets are small animals, usually not more than an inch or two long.

The oyster drill or dog whelk is a small snail. It uses its radulla (boney tongue) to bore a hole through the oyster's shell. It can then siphon out the soft body of the oyster. Its foot is not as efficient at adherence as that of the limpet. But its shell more completely surrounds the animal and it can withdraw into it for protection. A hard "trap door" called the operculum is pulled in to close the shell, making the snail less vulnerable to dessication and predation.

The moon snail (Polinices lewisii) has adapted to life on the sand. It can burrow into the sand in search of food. When the snail is moving the

mantle appears huge and covers much of the shell but the animal can completely withdraw for protection and close itself off with its operculum. The shells are lovely but the living animal is a menace to other mollusks. The moon snail uses its huge foot to smother its prey.

Two shells that are hinged together cover the compressed body of the bivalve. There is little evidence of a head, and the foot is developed to varying degrees depending on the species. It may be used for burrowing or as a site for secretion of special materials that attach the animal to a surface. Clams, mussels, oysters and scallops are all bivalves.

The clam lives a burrowing existence, using its muscular foot to dig down into sand or mud. Some clams are specially adapted for digging into much harder materials. When covered with water two siphons (sometimes fused) reach to the surface of the sand to draw in water and expell it, filtering out the desirable particles of food. Water travels through the clam's body very quickly; sometimes as much as three quarts may go through in an hour. Clams get food and oxygen from the water; they breathe through gills. The largest clams in Puget Sound are the geoducks which can get

up to 10 inches in length and 12 pounds in weight! There are giant clams in other parts of the world whose shell will average over three feet in length.

Attachment threads (byssal threads) are secreted by the foot of the mussel, a bivalve, which attaches it to hard surfaces. The byssal threads help guard the mussel against removal by a predator or by the surf. The animal can move slowly by breaking threads and laying down new ones as it creeps along on its foot. The siphons are much reduced or absent in the mussel, as there is no need for the animal to reach up through sand or mud in order to feed. The headless mussel has developed eyes and tentacles for tasting that are located around the edge of its shell.

The shells of the oyster have a much more irregular appearance than those of the clam, with one of the two shells permanently cemented to a hard substrate. This type of existence eliminates the need for a foot and siphons. Tidal currents and waves must bring food bearing water to the animal and carry away waste products.

The inside of oyster shells is smooth and beautiful. It is often used for making mother-of-pearl buttons, knife

handles, and other objects. Some oysters are also valuable for the pearls they create. A pearl is formed when a grain of sand or other foreign object invades the oyster's shell. Its soft body becomes irritated and manufactures layers of a covering around the object. These layers become the pearl.

The scallop favors deeper water with pebbly and shelly substrates, where it lies on one valve. It may be temporarily attached by a byssus thread similar to the mussel's attachment device. The clapping together of its shells propels the animal forward by jetting water out. When a predator is nearby the scallop can dart away quite quickly. Unlike other bivalves, the scallop has eyes and sensory tentacles arounds its shell to perceive its approaching enemies such as the starfish.

Octopuses, squids, cuttlefish, and nautili are all cephalopods, mollusks which have taken up a swimming existence. Cephalopods are characterized by a complex nervous system and a well developed head, from which projects a series of tentacles. The tentacles are used for seizing prey or holding onto rocks.

The chambered nautilus belongs to a very old group of cephalopods, and is the only

living representative of the class with a completely developed external shell. The shell is coiled planospirally (see glossary) and is divided into several chambers, the last one housing the living animal. The animal moves forward as it grows and lays down new chambers. A specialized organ secretes gas into the unoccupied chambers making the shell buoyant and allowing the animal to swim. The nautilus does not live near our coastline; it is a resident of tropical waters.

The eight armed octopus can swim but it is best adapted for a crawling existence. Suction discs on the arms aid it in movement and in catching prey. The octopus and other cephalopods release an ink when they are alarmed, confusing or repelling the enemy. The largest octopuses in the world (arm spread three meters, weight 100 pounds) are found in the Puget Sound. Most of these creatures are very shy.

ARTHROPODA

Members of this phylum have exoskeletons (see "Facts", Section III) and jointed appendages, and are divided into distinct body parts.

The greatest percentage of the marine arthropods belong to a group known as the crustaceans. Crabs, shrimps, lobsters, barnacles, isopods (the marine counterpart of the pill bug),

amphipods (including the so-called sand fleas) are all crustaceans. They are characterized by two pairs of sensory antennae, an external shall made of protein, and the presence of gills which are used in gas exchange and often associated with the appendages.

The horseshoe crab is commonly found in shallow waters in the northwestern Atlantic and the Gulf of Mexico. The appendages, or legs, which are hidden when the animal is viewed from the back) are used for moving through the soft, sandy bottoms on which it lives and for securing food. The horseshoe crab is not a crustacean or even a crab, but a member of the spider (Arachnid) family. Horseshoe crabs are really living fossils, unchanged after thousands of years of existence.

The shore crab uses four of its five pairs of legs for walking among rocks and in cracks in the intertidal zone. The first pair of legs have pinchers which are important for defense and for picking up pieces of food. Its strong exoskeleton provides the little crab with good protection. Most crabs live in water but the shore crab lives in the rocks of the intertidal zone of the beach.

ECHINODEMATA

The echinoderms, including the sea stars, brittle stars, sea urchins, sand dollars, and sea cucumbers, possess radial symmetry, a water-vascular system often used in locomotion, and an internal skeleton, consisting of spines, scales, and/or plates.

The common sea star or starfish has five arms whose undersides are equipped with a series of tube feet. The tube feet are actually small interconnected tubes filled with water; tiny suction cups are attached to the ends of the tube feet. These feet help the sea star move and make tight adherence to a rock or to its prey possible. The sea star wraps its body around a bivalve, then pulls its valves slowly apart with its powerful tube feet. The mouth is located at the center of the underside of the disc. Sometimes a stafish is injured; if a starfish loses an arm, a new one will grow in its place. This ability to grow new arms is called regeneration.

The moveable spines of the sea urchin (class Echinoidea) are a very good defense mechanism. The spines also grind holes in rocks to make homes for the sea urchins. The urchins' tube feet are responsible for locomotion and for capturing bits of food and moving them down to the underside of the animal, where the mouth is

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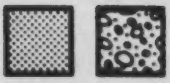
located. Aristotle's lantern, a five toothed appartus associated with the mouth is used for tearing up pieces of food.



The body of the sea cucumber is quite gelatinous feeling, as the exoskeleton is greatly reduced. The body actually feels more leathery than spiney. Unlike the sea urchin and the sea star, it lies with the side of its body to the sea bottom rather than its oral end. Tube feet move the animal slowly along, although some species are adapted for burrowing. The sea cucumber's mouth is surrounded by a series of tentacles, part of the water-vascular system, which capture bits of food when the animal holds them up in the water or brushes them across the bottom surface.

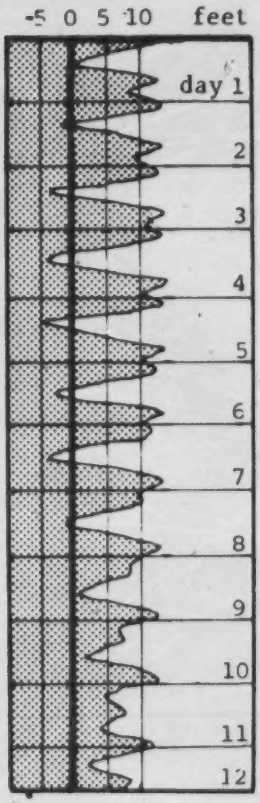
CHORDATA

Chordates possess gill slits or pouches, a dorsal nerve chord, and a structure called a notocord at some point in their life histories. Invertebrate chordates include sea squirts and salps. The majority of species in this phylum are vertebrates or animals with backbones such as fish, whales, and people. Fish and marine mammals will be discussed later.

Section II: The Seashore Environment

In simple terms a beach exists where the sea meets land. However, it is here that the simplicity ends. Beach environments are determined by three major factors: (1) the effect of tidal currents and wave action on the beach, (2) material composition of the beach; and (3) the length of time that any level of the

TIDES AND WAVE ACTION



The seashore is constantly in motion making it necessary for special animal adaptation. The movement of the tides and wave action are very important in providing food and oxygen as well as carrying away eggs, larvae, spores, and wastes. Some areas are protected (such as bays in Puget Sound) while others are completely exposed (such as on the open coast or a headland).

Forces involved in creating the rise and fall of tides include the earth in motion, the wind (as produced by the sun's heat), and the gravitational pull of the sun and primarily the moon. The moon pulls on the near side of the earth harder than on the center of the earth, and on the center harder than the far side. Thus, the moon pulls a bulge of water out on the near side of the earth, and leaves behind a bulge of water on the far side of the earth. The water tries to stay bulged toward and away from the moon. As the earth rotates on its axis once a day,

most people observe two high and two low tides as they pass in and out of the two bulges. The shapes and locations of land masses greatly complicate this phenomenon causing local variations in the times for high and low tides as well as the difference between the highest and lowest tide mark. On the Pacific Coast tides rise and fall twice a day, varying between 1 foot and 50 feet in various areas. The tides of Puget Sound may fluctuate as much as 15.5 feet.

BEACH TYPES

Depending on a variety of factors, beach types may consist of rock, sand, gravel, mud, or clay. In general rocky or sandy beaches exist on the open coast. Around bays and estuaries there can be rocky, gravelly, sandy, or muddy beaches. Clay beaches are uncommon in the Puget Sound area.

Rocky Beaches

Rocky beaches are usually made of solid, immovable bedrock. Wave action carries the sand and gravel away. Beachcombers will find more animals visible here. Plants and animals attach themselves to the rock and have adapted well to the crashing waves.

Gravel Beaches

Many gravel beaches exist in Puget Sound. Most life exists in the beach where gravel is mixed with sand and burrowing

animals can adjust. On the gravel beaches of the outer coast, wave action is strong; few animals survive except for the clam.

Sandy Beaches

Sandy beaches are homes for good diggers such as the razor clam who can adjust to the constant movement. Animals best suited for rocky beaches cannot attach to a sandy surface.

Mud Beaches

Mud beaches exist only in protected waters. They have a distinctive odor due to the great amount of decomposing plant and animal matter. This matter can be a food source or a threat because the matter depletes the supply of oxygen used by marine organisms. Clams and burrowing worms seem to adapt best to this type of beach.

Clay Beaches

Clay beaches are rare and combine the worst features of mud and rock beaches. The clay is too hard for burrowing, yet not stable nor hard enough to provide life for animals needing to attach permanently. This is a mostly barren area except for burrowing clams.

One must not assume that in one area there will only be clay, mud, sand, gravel, or rock. There is generally a mixture of materials. One type of

material is usually predominant, however.

ZONATION

Zonation is a particular way we divide intertidal areas into zones by the level of the tides. While strolling along a rocky beach at low tide it will become apparent that certain groups of plants and animals prefer a certain level or zone.

Some barnacles may be observed high up on the beach while sea stars tend to be closer to open water. Several factors are involved in this characteristic horizontal banding of plants and animals. Competition for space, ability to withstand dessication (drying out), and the location of a food source or a predator all affect the location of intertidal animals.

A sea star cannot venture outside of the water for prolonged periods of time, and must therefore live in a zone that is not frequently exposed. If a mussel settles into the sea star's territory, it may very well be eaten. These animals live much more successfully higher in the intertidal, where they are more apt to avoid predation. However, they too have a limited tolerance to dessication. The barnacle survives well very high in the intertidal zone because it can withstand long periods of exposure. Attempts at settling lower down often result in

predation or in crowding out and crushing by the larger and faster growing acorn barnacle. It is not only the drying out by sun and wind that limits the length of time organisms can live out of water. Waste products build up within plants and animals and without a means of frequently flushing them out, they may become poisonous to the organisms.

Zone 1, Splash Zone

The splash zone is at the uppermost portion of the beach where animals are wetted only by waves or spray at high tide. Periwinkles and pill bugs live here.

Zone 2, High Intertidal

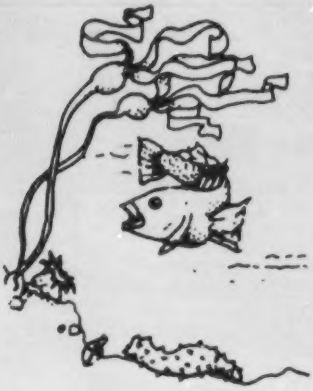
High intertidal is an area which is wetted only during high tides. The animals of this zone, such as the barnacle, are exposed to more air than water.

Zone 3, Middle Intertidal

The middle intertidal is usually covered and uncovered twice a day. The animals are adapted to spending about equal amounts of time in and out of the water.

Zone 4, Low Intertidal

The low intertidal zone is uncovered only by very low or minus tides. The animals of this zone can tolerate exposure to the air for only short periods of time.



Zone 5, Subtidal

The subtidal exists below the lowest tide. This area of the beach is never exposed.

The width of a particular zone depends upon the slope of the beach. The zones may be very narrow on a vertical piling or very wide on a gently sloping beach.

The concept of intertidal zonation is complicated, and the existence of so many substrate types adds another variable to the location of organisms on the beach. A plant or animal may be adapted for life on a rocky or gravelly shore, or it may need sand or mud in which to live. Rocky beaches are usually picked as sites for beach exploration because the organisms are easily visible, living on the surface or under moveable rocks. A glance at the surface of a sandy or muddy beach may be quite uninspiring, but by digging down one can find a myriad of creatures.

The term habitat may be broadly viewed as a place where a plant or animal lives...its natural environment. A tidepool provides a certain type of habitat, as does a piling on the wave swept coast. Even the holdfast of some seaweeds can be a habitat for certain animals. A particular habitat may be defined by its substrate type, the amount and type of

water it comes in contact with, and by many other factors. A plant or animal's habitat is its home.

Interesting beaches to visit in the Seattle area include Lincoln Park and Alki Point in West Seattle, Discovery Park in Magolia, and Golden Gardens in Ballard. Rocky beaches at all of these areas provide us with a firsthand look at intertidal zonation. Each beach also has sandy areas so that differences in substrate types and the animals they attract can be examined.

Section III: Endo- and Exo- Skeletons

A skeleton is a hard structure which lends support to an animal, aids it in its movement (in conjunction with muscles), and may provide protection. An endo-skeleton is an internal skeleton. Fish, whales, and people all possess endo-skeletons, while crabs and lobsters have exoskeletons. An exo-skeleton is an external skeleton. In some cases, an animal may have both types; for example, a bird has a boney internal skeleton and its feathers can be considered part of an exoskeleton. There is disagreement as to what constitutes a true skeleton. Some would argue that the shell of a mollusk could not be termed an exoskeleton, as it is not as closely associated with the living animal as the exoskeleton of a crab or the endoskeleton of a fish. (Shells are usually attached to mollusks at only two hinges.) For the purposes of this unit, defining a mollusk shell as an exoskeleton is completely appropriate.

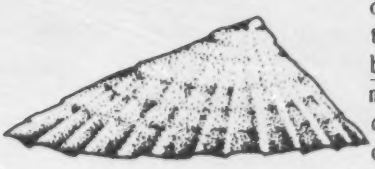
The word skeleton will be used to describe the hard structure of three phyla or groups we will examine in this unit:

1) Mollusks, which include animals with shells,
2) Anthropods such as the crustaceans, crabs and lobsters; and
3) Vertebrates, including animals with backbones.

In addition, information can be found on sponges and coral which do not belong to the three major groups mentioned.

Before preceding, one point should be discussed. The students may ask if the shells or bones are "alive". It is a difficult question to answer. Although bones and shells are not alive, they are produced by organisms that are alive, or were once alive. We say they are organic. An organic substance may be living or nonliving; for example, our hair and nails are composed mainly of dead protein. Nails, claws, and hooves are all closely related. The composition of endo-and exo-skeletons will be further explored in the phyla descriptions of each group.

MOLLUSKS



The one-shelled univalve creatures such as the snails (Gastropods) and limpets are mollusks. Clams, mussels, and oysters have two shells hinged together and are referred to as bivalves. They are also mollusks. These shells are chemically made up of calcium carbonate (for the most part), which is secreted or manufactured by a special part of the body called a mantle. The shell is produced in layers. With protein fibers and other non-living substances between layers, the shell is incredibly strong. The variety of colors is due to pigment

deposits. As the animal grows, the shell is enlarged. We refer to these shells as exoskeletons.

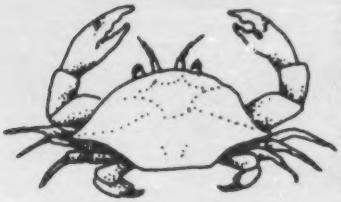
In the limpet, the outer edges are constantly added to in order to enlarge the shell. For snails, the mature shell is coiled in a spiral. The shell starts out as a cap on the back of the soft body. As the snail's soft body develops it bulges back and upward, ending up in a spiral. Since the soft body grows in a spiral, the shell does also, ending with a point.

The snails also have a hard door to completely close up inside their shell. This is called the operculum and is made from a specialized protein called conchilion.

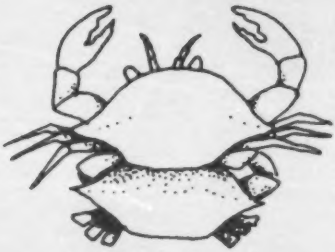
For most bivalves the enlargement of the shell develops in a different pattern. In examining a clam, mussel, or oyster, look for growth which occurs in concentric lines or ridges going out from the hinge (the oldest part of the shell). When food has been plentiful, the area between the ridges is greater. One can discover the age of the animal by counting the ridges. In most cases one ridge indicates a year. As more layers are added, the older layers get thicker.

ARTHROPODS

crab molt



Step 1



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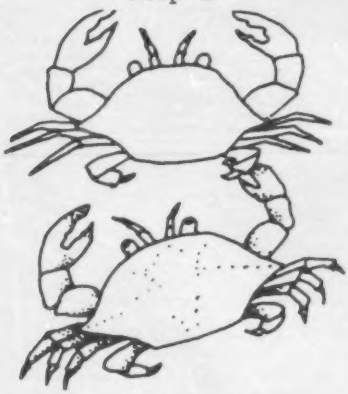


Step 3

Arthropods, including crustaceans (crabs and lobsters) and insects, also have exoskeletons but of a different chemical substance than mollusks. The exo-skeleton of a crab or lobster is secreted or manufactured by living tissue just beneath the skeleton. Different layers are secreted with the last being a waxy layer is a material called chitin which is formed with protein fibers and other materials to give strength and resistance to decay. The chitinous plates are rounded and thinner plates are rounded and thinner at joints and thicker at other sections with spines and ridges.

Crabs need to grow, but their close fitting "armor" could present a problem. It is for this reason that all arthropods must molt or shed their outer covering. Periodically, a new soft skeleton is secreted underneath the existing one. The animal then parts with its old covering and is left quite vulnerable until its new soft exoskeleton has a chance to harden by calcifying. (Calcium salts are deposited on the exoskeleton.)

VERTEBRATES

Animals with backbones are called vertebrates. Their skeleton is inside the soft body so is an endoskeleton. Basically, the endoskeleton is composed of bone and/or

cartilage. Sometimes bone is completely absent as in the shark skeleton made entirely of cartilage.

SPONGES and CORALS

Although sponges and corals do not fit in among the mentioned groups, they do have interesting skeletal structures. Sponges have a variety of skeletal types. The skeletons of the sponge can be (1) horny and fibrous as in bath sponges, (2) calcareous (composed of calcium carbonate) as in chalk sponges, and (3) of silica, as in glass sponges. Sponges cannot move about. After the animal dies, the skeleton remains. We do not have the sponges in the Pacific Northwest which make natural bath sponges. But there are many other varieties in Puget Sound.

Corals have an outer skeleton mostly composed of calcium carbonate. The skeletons of corals are responsible for building up huge coral reefs in tropical waters.

Section IV: Algae

Algae are members of the plant kingdom, more simple than most green land plants. Algae may be microscopic one-celled organisms called phytoplankton, or large attached marine plants called seaweeds. Varieties of algae can live and grow in any kind of aquatic environment. The fact that they live in water, which supports the plants, eliminates the need for special supporting tissues developed by land plants.

Most land plants need a special water conducting system in order to soak up water and nutrients from the soil. This system is not needed by algae as they live in such intimate contact with water. Algae have no true roots, leaves or stems, but they have definite parts for special functions.

Turkish towel

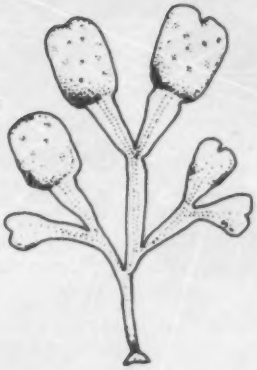
Sugar wrack (Laminoria saccharina), a brown algae, clearly shows the different parts of a seaweed. The holdfast, composed of many tangled fingerlike projections, attaches the plant to a hard surface or substrate. The holdfast takes on many different shapes in the different species. It may consist of a small disc, or many fine filaments. It may be hardly discernable. Most seaweeds need to be anchored down in order to complete their life cycles. If left floating in the water they may be tossed ashore where they would dry out

and die, or be carried into deeper, dark water where they could not get the light necessary for photosynthesis and survival. The stalk that arises from the holdfast is called the stipe. In the sugar wrack this leads to a broad leaf-like structure called the blade. The blades of seaweeds are responsible for soaking up light and nutrients, and they often contain reproductive structures. The bull kelp (Nereocystis lutkeana) has a very long stipe, swollen at the end into a bulb. The bulb floats to the surface and the blades arising from it are brought up into waters where light is sufficient for photosynthesis.

bull kelp

Algae range in color from a bluish-green to a golden brown. They fall into several different groups, distinguished from each other by the presence of different pigments. Seaweeds fall into three main phyla: Chlorophyta (green algae), Phaeophyta (brown algae), and Rhodophyta (red algae). As with land plants, the pigment chlorophyll allows algae to photosynthesize or manufacture their own food with the help of the sun. Animals cannot manufacture their own food.

Seaweeds take on many different shapes and textures. Several pressed samples are included in the kit but fresh samples



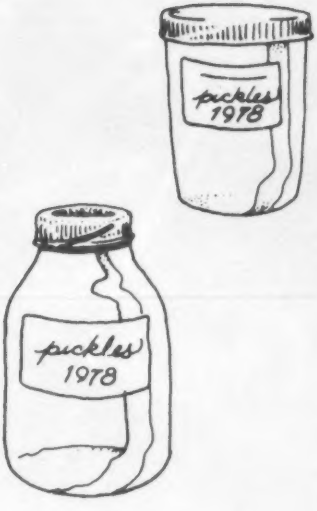
provide much better examples of what the plants are really like. The red seaweed turkish towel (Gigartina exasperata) is covered with many small protuberances which give the plant a very rough texture. Rockweed, or bladder wrack (Fucus) is a brown seaweed whose branches are swollen at the tips. These swollen tips, or bladders, house and protect the reproductive organs.

Seaweeds provide homes for many marine organisms. Snails may crawl around on them, worms may live in their holdfast, and crabs may hide under their blades. They provide nourishment for many animals including people. Different kinds of seaweeds are used in soups, casseroles, and many other dishes. The cell walls of many seaweeds cannot be digested by humans; therefore, these marine plants are used for enhancing flavor, adding texture, and providing roughage. Some seaweeds are used to make vitamin tablets. A substance called carageenan, extracted from certain red seaweeds, serves as a stabilizer and emulsifier in many foods, including ice cream. Algin, extracted from some brown seaweeds (such as rockweed) is used in the processing of many different products, including candy bars and some dairy products.

The following recipes are taken from Common Seaweeds of the Pacific Coast by J. Robert Waaland. The students may want to help in the preparation of these dishes, or the teacher may want to prepare them at home and bring them in for sampling.

Nereocystis Pickles

Gather approximately one large, healthy Nereocystis (bull kelp) plant per pint of pickles. Cut the cylindrical stipe into sections 6 to 8 inches long. Place the sections in a large kettle and bring to a boil for five minutes. Drain and rinse the sections then slice into thinner slices as for cucumber pickles. Boil slices for one hour until tender.



For the pickling juice, mix up the following ingredients (enough for 10 pints of pickles):

VINEGAR	2 pints
WATER	1 pint
LARGE ONIONS	3, chopped
SUGAR	3 pounds
LEMONS	3, sliced
CINNAMON BARK STICKS	6
WHOLE CLOVES	2 Tablespoons
MACE	a pinch

Add pickling mixture to the drained kelp slices. Cook for an hour, then seal in pint jars. You may also wish to experiment with other pickle recipes.

Blancmange

While this pudding recipe was really developed for use with Chondrus crispus (Irish moss), it will work with most of the carrageenan-containing seaweeds. Local species of Iridaia and Gigartina, which typically contain about 50 percent carageenan (percent dry weight), may be used as substitutes for Chondrus.

Thoroughly wash the seaweed in several changes of freshwater. Cut into small pieces; then put 1 cup of seaweed into a cheesecloth bag and tie the bag securely. Put the bag into 1 quart of milk in the top of a double boiler and cook over boiling water for 30 minutes. Stir occasionally and press the bag against the side of the pan with a spoon to extract as much carageenan as possible. If the milk is not stirred, the extract will tend to gel around the bag. After 30 minutes, remove and discard the bag. Add 1 to 1½ cups of sugar and a pinch of salt to the milk and allow to partly cool. When it begins to cool, add any fruit to flavor it, pour into molds and chill to set the gel.

Aspic recipes may also be made using seaweed gels instead of gelatin by heating the seaweed in vegetable juice instead of in milk.

Section V: Is It Fish or Mammal?

How do we decide whether a marine animal is a fish or mammal? Both are considered vertebrates, or animals with backbones, but unique features help us to distinguish one from another.

FISH

Fish are cold blooded, lay eggs, breathe underwater, and are generally covered with scales (skin reinforced with a bone) but no hair. The fish mentioned in the activity sets are the anchovy, salmon and perch; all fall into one class (Osteichthyes). They have gills, air bladders, and bones within their fins. An air bladder is a special gas-filled pouch located inside the front part of the fish's body. The gas, oxygen mixed with nitrogen, is lighter than water so helps the fish maintain its balance. The means the fish can stay in one place with little effort. The fish can move to higher or lower depths by taking in or letting out more gas.

Sharks, which are in another class of fish, do not have an air bladder and are also different in that their skeletons are not bone, but cartilage.

If students are curious about how fish breathe, it might help for you to understand how fish gills work. Fish do have nostrils, but these are used for smell only. When a fish

breathes, it opens its mouth to let in water. At the same time its gills, located on both sides, are closed in towards the body. When the fish's mouth closes, the gills open letting the water filter through blood vessels which absorb oxygen in the water and pass out wastes in the form of carbon dioxide.

a. gill
b. pectoral fin
c. pelvic fin
d. anal fin
e. caudal or tail fin
f. dorsal fin

The Anchovy

The anchovy has a slender, streamlined body, oval in width; a triangular-shaped and boney dorsal (back) fin; pectoral, pelvic and anal fins; plus a forked vertical tail fin. The tail fin is used for locomotion with the additional fins for turning. At the head is found a large mouth containing very tiny teeth which, in conjunction with hair-like filaments inside the gills, are used to filter plankton. The gills (as in all fish) take oxygen into the body from the water and let off carbon dioxide. The scales which cover most of the body are for protection from rubbing and infection, and for retention of body fluid. They are colored blue-green on top with white undersides. For added protection, anchovies travel in schools.

The Salmon

There are eight species of the salmonidae family commonly found in Washington's oceans. They inhabit the outer coastal

waters until they need to spawn. At that time, the male and female return to fresh water to lay or fertilize the eggs. During this phase the salmon change in shape and color. This family is characterized by a small adipose fin found on the back immediately in front of the tail fin. The eight common species are: Chinook salmon, Coho salmon, Pink salmon, Chum salmon, Sockeye salmon, Steelhead trout, Cutthroat trout, and Dolly Varden.

The Perch

Six species of seaperch are located in Washington's coastal waters. These fish frequent rocky areas or are found among pilings where kelp or mussels live. During the winter the seaperch tend to migrate out to deeper water. Movement is accomplished by rowing the pectoral (side) fins. Their bodies are oval in shape.

MAMMALS

Mammals, on the other hand, fall into only one class with many subclasses and orders. Mammals are warm-blooded with skin usually covered by hair. Mothers nourish their young with secreted milk. Four limbs can generally be located. A diaphragm is used for breathing. The marine mammals of major interest are porpoises, dolphins, and whales.

There is great confusion among laymen about the differences between whales, dolphins, and porpoises. Many use the common names interchangeably. Through the use of a classification system, it is hoped that some differences can be clarified. Information about each marine species used during the activities is given. They are all of the order Cetacea, class Mammalia.

The order Cetacea contains animals from 4 feet (porpoises) to 120 feet (blue whale). All of the cetaceans, commonly called whales, are legless and swim using their boneless horizontal tails called flukes. Females give birth to well-developed young who suckle the secreted milk from the mother. Whales are born tail first. Cetaceans are hairless except for a few bristles around the snout.

Being warm-blooded and needing some protection from the cold water, the cetaceans have blubber up to 10 inches thick surrounding their streamlined bodies, except for their tail flukes, dorsal fin, and flippers.

All cetaceans have 5 digits in their flippers and very similar bone structure when compared to land mammals, their ancient ancestors. The legs are no longer found externally in the usual form. It is thought that

whales took to water about 65 million years ago. The adaptation has become so complete that whales are never found on land unless they are diseased or have landed there accidentally. Whales can no longer survive on land.

Whales do have ears. They are small holes with large internal passages. Ear plugs grow inside the passages and researchers have found growth rings on these plugs, each corresponding to 1 or 2 years. The eyes are adapted for seeing underwater making them shortsighted on the surface. Murky waters make seeing difficult, however. Hearing is the most well-developed sense among this order. (See "Facts", Section VI). The one nostril, called a blowhole, is located at the top of the head. All cetaceans must come to the surface for air. Some dive for 10 minutes before taking another breath, others have been recorded to dive for two hours before surfacing.

The two major subdivisions for the order Cetacea are (1) the toothed whales (Odontoceti) which feed on medium to large prey and includes the smaller members plus the huge sperm whale; and (2) the whalebone or baleen whales (Mysteceti) containing the largest animals alive. (The blue whale ranges from 75 to 100 feet long.) The

latter's smallest member is the pygmy whale, 15 feet long. All baleen whales feed on planktonic shrimp or "krill". These whales can gather up to two tons of krill at one time.

Members of the order Cetacea have received a great deal of attention recently. Studies have shown that their brains are large and complex. A communication barrier prevents us from fully understanding the intelligence they possess, but that they are conscious or aware of what they do is widely accepted. Information on three popular species follow. (The models of these species are in the kit.)

The Bowhead or Greenland Right Whale

Species: Greenland Right Whale or Bowhead
Genus: Balaena
Family: Right whales (Balaenidae)
Suborder: Whalebone or Baleen Whales (Mysticeti)
Order: Cetacean

Bowhead

Bowheads range in length from 47-62 feet. They have a distinctive bump on their head. The head is about one third the body length. There are no teeth in the jaws of this whale. Instead there are baleen plates, numbering between 237 to 346 on each side of the upper jaw. The baleen has bristle hairs which filter "krill" or small shrimplike

animals when the bowhead sweeps through the water with its mouth open. The large tongue pushes the water out, leaving the krill to be swallowed. The jaw is dramatically arched. The body of the bowhead is plump.

Bowheads are found in Arctic waters (i.e., off the coast of Alaska and Greenland). Thick blubber keeps them warm. The bowhead whales horizontal tail fluke allows it to move in the water. The spade-like side fins help it turn. There is no dorsal (back) fin. It is black or dark gray with a white mark commonly found under its chin. Bowheads travel singly or in pairs, often in the company of Belukha or white whales.

The Killer Whale or Orca

Species:	Orca
Genus:	Orcinus
Subfamily:	Delphininae
Family:	Ocean Dolphins (Delphinidae)
Suborder:	Toothed Cetaceans (Odontoceti)
Order:	Cetacean

Male killer whales can grow to be 31 feet, weighing 2-4 tons; females up to 21 feet of 1,500-2,500 pounds. In the male the dorsal fin can stand 3-6 feet high while only 2 feet tall in the female. There is no bone in the fin and sometimes the fin will flop over to one side. The snout is blunt with a short beak. In coloration

its back is mostly black with patches of white, while its underside is white.

Orca

Killer whales are found in seas throughout the world and are nicknamed "fat choppers" by Norwegians because they race through schools of fish, chomping away. They return later to pick up pieces of fish. Within its mouth are contained 40-50 sharp teeth which interlock from lower to upper jaw creating an efficient trap.

Besides its tall, elongated, triangular-shaped dorsal fin, the killer whale has side fins which are very round, like ping-pong paddles. Its streamlined shape, fins, and powerful tail fluke allow it to move up to 34 miles per hour; it is difficult to catch.

Bottle-nosed Dolphin (Pacific)

Species:	Bottle-nosed Dolphin (Pacific)
Genus:	Tursiops
Subfamily:	Delphinidae (Ocean Dolphins)
Suborder:	Toothed Cetaceans (Odontocetti)
Order:	Cetacea

Dolphins are smaller than other toothed whales, the longest being about 12 feet long (male larger than female). The bottle-nosed dolphin is well known as it is easily kept in captivity. It is this species that provided T.V. fans with

Flipper. These 400 pound marine mammals are sometimes referred to as "cowfish" or the common porpoise (which can be very confusing). Its less concave dorsal fin is a clue for identification.

Their colors include a grayish or grayish-purple back with a V-shaped blackish mark on the sides of the head. It is white on the underside, having blackish flippers and flukes, and a white splotch on the upper side of the beaked nose.

The bottle-nosed dolphin, found from central California south along the coast, is not the fastest of its relatives, but it obtains speeds of up to 24 miles per hour. This speed is used when hunting in packs for fish. With the 18-26 pairs of sharp, conical teeth in <u>each</u> jaw, capturing fish is a <u>well</u> adapted skill.

Dolphin

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Section VI: Sounds and the Sea

WHAT IS SOUND?

Sound begins as a physical event - the movement of one object moving rapidly enough to send out waves through the medium in which it is vibrating. Sound requires a substance which will allow these vibrations to travel through. Usually we hear sound carried through the air. Once an object vibrates, it jars the air molecules around it and causes them to quiver and bump into other air molecules. This bumping eventually reaches the ear drum which in turn vibrates and triggers our response to the sound. Sound is both physical event and the sensory imputs in our brains caused by it.

The waves produced by the vibrations of the source radiate in every direction, but they move much faster than water waves. These sound waves are effected by the environment. Echoes bouncing off walls interfere with sound waves to deaden the sound. Carpets or curtains can absorb sound waves much like the porous sponge absorbs water.

HOW WE HEAR

Our outer ear helps "catch" and concentrate sound waves for delivery to our ear canal. Even concentrated, the force of air waves traveling through the ear canal and pushing on our ear drums is very light and must be amplified. At the ear drum, the sound waves are converted into mechanical

vibrations. The membrane of the ear drum vibrates and passes these vibrations on to three small bones in the middle ear (the hammer, anvil and stirrup). The hammer pushes on the anvil, which in turn pushes on the stirrup. Like levers, these movements serve to amplify the vibrations to the "oval window", a membrane that covers the opening of the fluid-filled cochlea in the inner ear. Scientists still do not fully understand what happens in the inner ear, but it is here where sound waves are changed from vibrations to nerve impulses. These impulses are sent to the brain by the auditory nerve and interpreted as sound.

ear

HOW FISH AND MAMMAL HEAR

Fish do not have a middle ear like we have. All fish have a lateral line which is a delicate mass of organs and nerve networks located along their sides. The lateral line does not see nor hear, but it does sense faint movements in the water. Fish can stay within their school by feeling the waves made by other fish.

Certain species of fish do have a middle ear, however. It is actually an air bladder linked by bones to the inner ear. The gas-filled bladder's prime function is to keep the fish afloat but it also vibrates when sound waves strike it. For fish that hear well, the bones of the middle ear carry

these vibrations to the inner ear which transforms them into nerve impulses. The inner ear of the fish is much like man's. Really acute hearing did not occur until fish became amphibians and the middle ear (for air) developed. In the ears of fish, the air bladder touches liquid on both sides; the water vibrations pass directly to the inner ear but are not amplified as in the mechanisms of our ears.

What about marine mammals then? Porpoises, for example, are like all mammals - they have a fluid-filled inner ear and a air-filled middle ear. Certainly the porpoises need special adaptations to their water environment.

The porpoise does not have a visible outer ear; it is like a pin hole concealed in the skin. Water fills the narrow ear canal; sounds vibrate in the canal lining. Unlike ours, the ear drum of the porpoise is a ligament that pulls on the three little bones of the middle ear. This pulling or cranking seems to amplify the sound and takes care of the barrier between the inner-ear fluid and the sound source. In fact, the hearing of whales and porpoises is so efficient, it has become their primary sense. Scientists tell us that water transmits sound better than air which also accounts for their acute hearing.

ECHOLOCATION

We have mentioned that porpoises and some whales make sound waves which create echoes used to furnish valuable information. This system is like sonar used by navies to locate submarines and study the sea bottom. The clicks made by a porpoise and the high pitched song of the humpback are mysteries to us. Whales and porpoises have no vocal cords; their noises do not come from their mouths. (Flipper and other porpoises are trained to move their mouths as if they are talking.) Scientists speculate the clicks and whistles come from (or near) their blowholes. There are air sacs and bony structure near the blowhole which may vibrate. Perhaps the blowhole can be modulated to produce different sound frequencies.

However they are produced, these sounds are to gain information about the topography of their environment, to locate food, and to communicate with members of their species. Research has shown us that whales and porpoises can find out about the size, position, and form of underwater objects. Since they do not see well in the dark water, this ability is necessary for locating their meals. The sheer size and speed of porpoises and whales also indicates that they must have special help for navigating.

Man's echolocation devices seem poor in contrast!

UNDERWATER ACOUSTICS

Man has long been interested in underwater acoustics. It is believed Aristotle was first to observe that sound would travel in water. Later Leonardo de Vinci noted that he could hear ships at great distances when he placed his ear next to the opening of a long tube extending into the sea. However, real interest did not develop until the nineteenth century. Sounds traveling through air were especially unreliable in fog. Sailors began to wonder if ships' communications could be improved with underwater transmission of sound. One of man's earliest uses of underwater sound was the introduction of submerged bells on light ships. These bells could be heard far away with the use of a simple microphone attached to the hull of another ship.

Glossary

adipose fin - an additional dorsal fin in certain fishes consisting mostly of fatty tissue.

algae - simple, photosynthetic plants with single organs of reproduction; aquatic plants, marine or fresh water.

algin - a gelatinous substance obtained from certain algae; used as a thickener and emulsifier.

baleen - plates of keratin which hang from the upper jaw on each side of the mouth of the toothless whalebone whales.

bivalve - animal with a shell in two parts hinged together.

blade - the flat, expanded part of a leaf or similar structure, usually refers to seaweeds.

byssal thread/byssus - a mass of filaments by means of which certain mollusks, such as mussels, attach themselves to fixed surfaces.

calcareous - relating to materials composed of or containing calcium carbonate.

calcium carbonate - a colorless compound, $CaCO_3$, occurring naturally as chalk, limestone or marble.

chiton - a hard, waterproof, inelastic secretion forming the exoskeleton of such arthropods as the lobster.

conchilion - specialized protein from the shell of mollusks.

dessication - the drying out of an organism due to heat, wind, and other forces.

dorsal - relating to the back.

echolocation - the ability of an animal that emits high-frequency sounds to orient itself by means of the reflected sound waves.

endo-skeleton - internal skeleton

exo-skeleton - external skeleton

habitat - place with a particular kind of environment inhabited by organisms.

holdfast - the basal, rootlike formation by which certain seaweeds or other algae are attached to a surface.

lateral line - system of sense organs, present in aquatic vertebrates; detects pressure changes including vibrations.

mantle - fold of skin covering whole or part of body of mollusks; outer surface secretes shell.

notocord - skeletal rod lying lengthwise between central nervous system and stomach; in most vertebrates occurs complet only in embryo.

operculum - exo-skeletal plate of some gastropods (e.g., snails), which can close opening of shell when animal withdraws into the latter.

photosynthesis - in green plants, synthesis or organic compounds from water and carbon dioxide using energy absorbed by chlorophyll from sunlight; source of most of our oxygen.

phytoplankton - minute, floating aquatic plants.

planospirally - a spiral in which the coils lie in one plane; one coil contained within another.

predation - the act of one animal capturing and eating another.

radial symmetry - symmetry based around a central point or line.

regeneration - ability of an organism to restore tissue or organs which has been removed.

silica - glassy mineral found in various forms, including sand and quartz.

sonar - a device that sends sound waves through water and picks them up after they strike some object and bounce back.

stipe - a stalk or stalklike structure.

substrate - a layer of earth or rock that lies directly under another.

univalve - referring to an animal with a one piece shell.

vertebrates - animals having a backbone.

vibration - rapid motion back and forth.

zones/zonation - a rock bed or an area characterized by a common property, such as fossils or minerals.